



(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication of patent specification :
25.01.95 Bulletin 95/04

(51) Int. Cl.⁶ : **H01M 6/18, H01B 1/12,**
G02F 1/15

(21) Application number : **91203304.0**

(22) Date of filing : **14.12.91**

(54) **Solid polymer electrolyte based on cross-linked polyvinylether.**

(30) Priority : **21.12.90 IT 2248290**

(43) Date of publication of application :
01.07.92 Bulletin 92/27

(45) Publication of the grant of the patent :
25.01.95 Bulletin 95/04

(84) Designated Contracting States :
AT BE CH DE DK ES FR GB GR LI LU NL SE

(56) References cited :
EP-A- 0 312 160

(73) Proprietor : **ENIRICERCHE S.p.A.**
Corso Venezia 16
I-20121 Milan (IT)

(72) Inventor : **Marchese, Luca**
Via Riccardo Pitteri, 4
I-20134 Milan (IT)
Inventor : **Roggero, Arnaldo**
Via Libertà 72
I-20097 San Donato Milanese (Milan) (IT)
Inventor : **Andrei, Maria**
Via Perini, 1
I-43042 Berceto (Parma) (IT)
Inventor : **Prosperi, Paola**
Via Roberto Bracco, 78
I-00137 Rome (IT)

(74) Representative : **Fusina, Gerolamo et al**
Ing. Barzanò & Zanardo Milano S.p.A,
Via Borgonuovo, 10
I-20121 Milano (IT)

EP 0 492 710 B1

Note : Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid (Art. 99(1) European patent convention).

Description

This invention relates to a solid polymer electrolyte based on cross-linked polyvinylether, the process for its preparation and its use in electrochemical devices which incorporate it.

Solid polymer electrolytes (also known as ion-conducting polymers) are known in the art, and consist of a solid solution of an ionic compound entirely dissolved in a solid plastic macromolecular substance, this latter being the product of polymerizing monomers containing at least one heteroatom, especially oxygen.

Said macromolecular material is usually polyethyleneoxide or another polyether, as described for example in US patent 4,471,037, French patents 2,253,769 and 2,568,574, and European patent 13199.

The problems connected with these solid polymer electrolytes relate generally to the fact that they usually demonstrate an ionic conductivity which is satisfactory only at higher than ambient temperature, and that the electrolytic membranes have poor mechanical strength and poor dimensional stability. All this makes the solid polymer electrolytes of the known art of little interest for practical use.

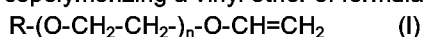
The object of the present invention is to overcome the aforesaid drawbacks of the known art.

Specifically it has been found, according to the present invention, that a copolymer obtained from a vinyl ether containing ethyleneoxide groups and another vinyl ether which also contains an allyl termination can be hydrosilylated at its allyl unsaturation by reaction with a trialkoxy silane. It has also been found that such a hydrosilylated copolymer is soluble in organic solvents, and can be easily homogenized with ionic compounds and be cross-linked with a diprotic cross-linking agent.

An electrolytic membrane can therefore be prepared having excellent mechanical and dimensional characteristics and able to exhibit good ionic conductivity even at relatively low temperature.

In accordance therewith, the present invention firstly provides a solid polymer electrolyte in membrane form, consisting of a solid solution of an ionic compound dissolved in a polyether, characterized in that said electrolyte is obtained by:

a) copolymerizing a vinyl ether of formula:



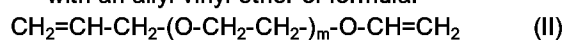
where

R is a methyl or ethyl radical

n is a whole number between 1 and

16,

with an allyl vinyl ether of formula:



where m is a whole number between 1 and

10,

the molar ratio of (II) to (I) being between 1/100

and 10/100, to obtain a copolymer having allyl unsaturations;

b) hydrosilylating the allyl double bond of the copolymer obtained in stage a) by reaction with an alkoxy silane chosen from trimethoxy and triethoxy silane, to obtain a hydrosilylated copolymer;

c) cross-linking the hydrosilylated copolymer obtained in stage b) by means of a diprotic cross-linking agent, operating in solution in an organic solvent in the presence of an ionic compound, and evaporating the solvent to obtain a membrane.

In stage a) according to the present invention, a copolymer is prepared by cationic polymerization of a vinyl ether (I) and an allyl vinyl ether (II) in the aforesaid molar ratios. The vinyl ether (I) can be easily prepared by reacting ethyl vinyl ether with a polyoxyethylene glycol mono-methyl or mono-ethyl ether.

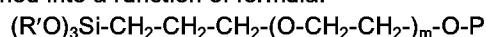
The allyl vinyl ether (II) can be easily prepared by reacting an ethylene chlorohydrin vinyl ether (itself prepared by transvinilation of ethylene chlorohydrin) with allyl alcohol operating in a solvent such as dimethylsulphoxide, in the presence of a base such as potassium hydroxide at a temperature of the order of 80°C. The monomers (I) and (II) are obtained with a purity exceeding 99% using normal separation methods.

Conveniently, the copolymerization reaction is conducted in an inert solvent at a temperature of about -75/-80°C in the presence of a Friedel-Crafts catalyst used in a quantity of between 0.8 and 1.0 moles per 100 moles of the monomers (I) and (II). Examples of catalysts suitable for the purpose are boron trifluoride etherate, aluminium trichloride, alkylaluminium halides and tin tetrachloride. Examples of solvents suitable for the purpose are hydrocarbons such as heptane, benzene and toluene, and chlorinated hydrocarbons such as dichloromethane. Under the aforesaid conditions the polymerization time is of the order of 1-3 hours.

On termination of the polymerization the catalyst is deactivated by adding an aliphatic alcohol such as methanol, and the polyvinylether is recovered by normal methods for separating a polymer from an organic solvent solution. The copolymer obtained in this manner can be characterised by analysis techniques such as proton NMR spectra methods, by which the ratio of the comonomers in the copolymer can be determined. The copolymer has a weight-average molecular weight of the order of 20,000-100,000 and a glass transition temperature, determined by DSC, of between -65 and -80°C.

In stage b) of the present invention, the allyl function of the copolymer prepared in stage a) is subjected to hydrosilylation by reacting with an alkoxy silane chosen from trimethoxy and triethoxy silane. In this manner the allyl function in the copolymer is trans-

formed into a function of formula:



where:

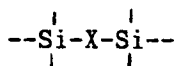
R' indicates methyl or ethyl;

P schematically indicates the polymer.

More specifically, the copolymer after careful drying is functionalized with a trialkoxy silane operating in solution in an anhydrous inert solvent at a temperature of the order of 80-100°C in the presence of a catalyst containing a transition metal added in a concentration of the order of ppm (parts per million).

Examples of solvents suitable for the purpose are hydrocarbons such as hexane, cyclohexane, benzene and toluene. Examples of catalysts suitable for the purpose are hexachloroplatinic acid, tris(triphenylphosphine) rhodium chloride and dicobalt octacarbonyl. The copolymer functionalization is verified by ¹H and ¹³C NMR spectroscopy, after removing the solvent and the excess trialkoxy silane under vacuum.

In stage c) of the present invention the hydrosilylated copolymer is cross-linked, in the presence of an ionic compound, by suitable diprotic compounds as cross-linking agents, to generate siloxane bridges of type:



where X can be O or (O-CH₂-CH₂)_k-O, k being a whole number from 1 to 7. The cross-linking agent can be water or an ethylene glycol acidified with HCl and added in a quantity of about 10-20 microlitres per gram of polymer. Ionic compounds suitable for this purpose are salts and especially perchlorates, borates, fluoroborates, thiocyanates, trifluoroacetates and trifluoromethanesulphonates of metals (monovalent or polyvalent) and especially lithium, sodium, potassium, calcium, copper, zinc, magnesium, lead, tin and aluminium, used in a quantity such as to achieve an atomic ratio of oxygen in the polyether to metal of between about 4/1 and 18/1. Lithium salts are preferred for the purpose, and in particular lithium perchlorate, in which case the preferred ratio is about 12/1. Stage c) can be conducted by dissolving the hydrosilylated polyvinylether and the ionic compound (preferably a lithium salt) in a suitable anhydrous solvent (preferably acetonitrile) in an inert atmosphere. The cross-linking agent is then added to the solution in a quantity of about 5 times the equivalent reactive sites on the silane in moles. The solution is then poured into a suitable mould, preferably of Teflon®. The reaction between the alkoxy silane groups and the cross-linking agent takes place during the evaporation of the solvent. This reaction can also be completed after the solvent evaporation, during the drying to eliminate volatile substances, this being achieved by heating to about 40°C under vacuum. In all cases an

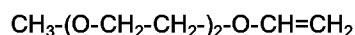
insoluble, elastic, transparent membrane of 50-200 μm (micron) thickness is obtained having good ionic conductivity at ambient temperature.

The solid polymer electrolyte of the present invention is obtained in this manner, consisting of a solid solution of an ionic compound in the solid polyether cross-linked during membrane formation. This polymer electrolyte can be used as an electrolytic separator in electrochemical devices, as optical and electrochromic displays and as electrochemical generators and sensors.

The following experimental examples are provided to illustrate the invention without in any way representing a limitation to its scope.

EXAMPLE 1

Preparation of the vinyl ether:

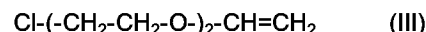


Ethyl vinyl ether (1.8 moles), diethyleneglycol monomethyl ether (0.6 moles) and mercuric acetate (5.7 x 10⁻³ moles) are fed into a three-neck flask of 500 ml capacity provided with a reflux condenser and maintained under a nitrogen stream. The mixture is heated to reflux temperature and maintained under reflux conditions for 10 hours. During this time the temperature rises from an initial value of 39°C to a final value of 42°C. The reaction is then extinguished by adding solid potassium carbonate and the mixture distilled firstly at atmospheric pressure to eliminate the excess ethyl vinyl ether and the ethyl alcohol, a by-product of the reaction, and then under reduced pressure (26.6mbar or 20 torr) to separate the vinyl ether of the title from the unaltered diethyleneglycol monomethyl ether.

The vinyl ether produced in this manner has a purity exceeding 99%, and a yield of about 80% on the initial diethyleneglycol monomethyl ether. The structure is confirmed by NMR and IR spectroscopy and mass spectrometry.

EXAMPLE 2

Preparation of the diethylene chlorohydrin vinyl ether:



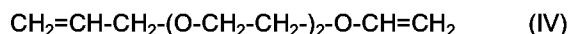
315 ml (3.3 moles) of ethyl vinyl ether and 12.5 mmoles of mercuric acetate, which rapidly dissolves, are fed into a three-neck flask of 500 ml capacity provided with a reflux condenser and mechanical stirrer and maintained under a nitrogen stream. 0.660 moles of diethylene chlorohydrin are dripped into the solution, the mixture then being heated under reflux until the ratio (gas-chromatographic analysis) of the chlorohydrin to the corresponding vinyl ether remains constant (20 hours). The mixture is then treated with an-

hydrous potassium carbonate (20 grams), most of the excess ethyl vinyl ether and by-product ethyl alcohol are removed under vacuum and the remaining mixture is filtered through a Gooch crucible. The filtrate is diluted with chloroform and extracted with water, the organic phase being dried with anhydrous sodium sulphate and filtered. After evaporating the solvent, the crude product is purified by preparative HPLC (stationary phase silica gel).

The chlorohydrin vinyl ether is obtained with a yield of 60% (colourless liquid, purity 99%) and is characterised by mass, FT-IR and NMR spectrometry.

EXAMPLE 3

Preparation of the allyl vinyl ether:



250 ml of dimethylsulphoxide, 55 grams (986 mmoles) of ground potash and 34 ml (500 mmoles) of distilled allyl alcohol are fed into a three-neck flask of 500 ml capacity provided with a reflux condenser and mechanical stirrer and maintained under a nitrogen stream. The mixture is left stirring for 1 hour, after which 62.5 grams (415 mmoles) of ethylene chlorohydrin vinyl ether (III) are dripped in slowly. When the addition is complete the reaction mixture is heated to 80°C for 2 hours, after which gas chromatographic analysis shows that the reaction is complete. The mixture is treated by pouring the flask contents into cold water (about 500 ml) and extracting with three 250 ml portions of chloroform. The pooled organic phases are washed with water until neutral and then dried with anhydrous sodium sulphate. The chloroform is removed in a rotary evaporator, after which the crude reaction product, about 40 grams of yellowish oil, is distilled under vacuum (0.0133mbar or 0.01 mmHg), to finally obtain 30 grams of pure diethyleneglycol allyl vinyl ether (colourless liquid). The structure is confirmed by mass, FT-IR, ¹H and ¹³C NMR spectrometry.

EXAMPLE 4

Copolymerization of vinyl ether and allyl vinyl ether.

58 mmoles of monovinyl ether of Example 1 and 1.16 mmoles of allyl vinyl ether of Example 3 dissolved in 20 ml of anhydrous methylene chloride are fed into a reactor in the form of a 50 ml test tube fitted with a spiral mechanical stirrer and nitrogen and reagent feed inlets. The mixture is cooled to -78°C and 0.63 mmoles of BF₃ etherate dissolved in 2 ml of anhydrous CH₂Cl₂ are added under vigorous stirring. A certain increase in viscosity is observed after 45 minutes. After 2 hours the viscosity is high and turbidity is observed. The polymerization is then interrupted by

adding an excess of methanol (2 ml) and the product allowed to reach ambient temperature, on which it is taken up in methylene chloride and poured into 100 ml of water and bicarbonate, the organic phase being separated, washed with water and finally dried with sodium sulphate. After solvent removal and prolonged treatment at 50°C under vacuum (0.0133mbar or 0.01 mmHg) a colourless sticky product is obtained. The yield is quantitative. The copolymer is characterised by FT-IR and NMR spectroscopy, confirming the presence of the allyl function bonded to the polymer. DSC analysis confirms that the polymer is amorphous (T_g = -71°C).

EXAMPLE 5

Hydrosilylation of the copolymer.

The copolymer solution (5 grams in 20 ml of anhydrous toluene) obtained by the procedure described in Example 4 is fed into a 50 ml tailed test tube in a nitrogen atmosphere, after which an excess of triethoxy silane (2.5 mmoles) over the molar double bond content (4:1) is added, finally injecting 50 microlitres of a 3.3% hexachloroplatinic acid (H₂PtCl₆) solution in isopropanol. The reactor is hermetically sealed with a screw stopper and the nitrogen flow interrupted. The reaction is conducted for 7 hours at 100°C, the mixture left to return to ambient temperature and then siphoned under nitrogen into a 250 ml flask. The solvent and the excess triethoxy silane are removed under vacuum (0.0133mbar or 0.01 mmHg) by heating to 45°C for several hours. The polymer maintains the same appearance as the starting material and is only slightly coloured. Characterisation by FT-IR and NMR confirms the disappearance of the double bonds, the presence of the bonded triethoxysilane group and the absence of Si-H groups.

EXAMPLE 6

Preparation of the electrolytic membrane.

The hydrosilylated polyvinylether-based electrolytic membrane is prepared by the following procedure conducted in a glove box in an argon atmosphere:

- a solution consisting of the hydrosilylated polyvinylether and the lithium salt in acetonitrile is prepared;
- a small quantity of water or ethyleneglycol acidified with HCl is added to this solution and the mixture is homogenized at ambient temperature;
- the solution obtained is poured into teflon moulds and the moulds placed in an argon forced circulation chamber to gradually remove the solvent and other volatile substances;

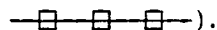
- after some days, necessary for completion of the cross-linking reaction, the electrolytic membrane is heated to 40°C under reduced pressure for 4 or 5 hours.

In this manner a transparent homogeneous membrane of about 100 micron thickness is obtained which can be easily removed from the teflon mould and made to adhere to the surface of the electrode used for the conductivity measurements.

Confirmation of the cross-linking of the polymer subjected to this treatment is confirmed by the evident improvement in the mechanical characteristics of the material and the fact that when such membranes are re-treated with acetonitrile they swell. This method was used specifically to prepare an electrolytic membrane from 1 gram of the copolymer of Example 5 and a quantity of LiClO_4 such as to obtain an EO(ethyleneoxide)/Li ratio of 10. The two components are dissolved in 10 ml of anhydrous acetonitrile in an argon atmosphere; 20 microlitres of diethyleneglycol acidified with HCl (0.05 mmoles per mmole of diethyleneglycol) are added to the solution as cross-linking agent. In an identical manner an electrolytic membrane is prepared from a polymer containing a vinyl ether (I) where $n = 4$. These membranes are about 100 μm (micron) thick. The conductivity of the membranes at various temperatures is shown on the graph of the Figure ($n = 2$ for



and $n = 4$ for



The electrolytic membranes are amorphous and have glass transition temperatures of about -40°C.

Claims

Claims for the following Contracting States :
AT, BE, CH, DE, DK, FR, GB, GR, LI, LU, NL, SE

1. A solid polymer electrolyte in membrane form, consisting of a solid solution of an ionic compound dissolved in a polyether, characterised in that said electrolyte is obtained by:
 - a) copolymerizing a vinyl ether of formula

$$\text{R}-(\text{O}-\text{CH}_2-\text{CH}_2)_n-\text{O}-\text{CH}=\text{CH}_2 \quad (\text{I})$$
 where R is a methyl or ethyl radical
 n is a whole number between 1 and 16,
 with an allyl vinyl ether of formula:

$$\text{CH}_2=\text{CH}-\text{CH}_2-(\text{O}-\text{CH}_2-\text{CH}_2)_m-\text{O}-\text{CH}=\text{CH}_2 \quad (\text{II})$$
 where m is a whole number between 1

and 10,
the molar ratio of (II) to (I) being between 1/100 and 10/100, to obtain a copolymer having allyl unsaturations;

b) hydrosilylating the allyl double bond of the copolymer obtained in stage a) by reaction with an alkoxy silane chosen from trimethoxy and triethoxy silane, to obtain a hydrosilylated copolymer;

c) cross-linking the hydrosilylated copolymer obtained in stage b) by means of a diprotic cross-linking agent, operating in solution in an organic solvent in the presence of an ionic compound, and evaporating the solvent to obtain a membrane.

2. A solid polymer electrolyte as claimed in claim 1, characterised in that in stage a) the copolymer is prepared by cationic polymerization in an inert solvent at a temperature of about -75/-80°C in the presence of a Friedel-Crafts catalyst in a quantity of between 0.8 and 1.0 moles per 100 moles of the monomers (I) and (II), the copolymer obtained having a weight-average molecular weight of the order of 20,000-100,000 and a glass transition temperature of between -65 and -80°C.
3. A solid polymer electrolyte as claimed in claim 1, characterised in that in stage b) the copolymer prepared in stage a) is reacted with an alkoxy silane chosen from trimethoxy and triethoxy silane, operating in solution in an anhydrous inert solvent at a temperature of the order of 80-100°C in the presence of a catalyst containing a transition metal.
4. A solid polymer electrolyte as claimed in claim 1, characterised in that in stage c) the hydrosilylated copolymer is cross-linked, using a cross-linking agent chosen from water and an ethyleneglycol acidified with HCl and added in a quantity of about 10-20 microlitres per gram of copolymer, operating in an organic solvent and preferably acetonitrile, in the presence of an ionic compound chosen from the salts and especially perchlorates, borates, fluoroborates, thiocyanates, trifluoroacetates and trifluoromethanesulphonates of metals (monovalent or polyvalent) and especially lithium, sodium, potassium, calcium, copper, zinc, magnesium, lead, tin and aluminium, in a quantity such as to achieve an atomic ratio of oxygen in the polyether to metal of between about 4/1 and 18/1.
5. A solid polymer electrolyte as claimed in claim 4, characterised in that the ionic compound is a lithium salt and preferably lithium perchlorate, the atomic ratio of oxygen in the polyether to lithium

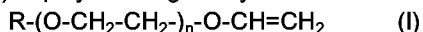
being of the order of 12/1.

6. A solid polymer electrolyte as claimed in claim 4, characterised in that the solution is poured into a mould, the solvent is evaporated and the evaporation residue dried to obtain a membrane having a thickness of between 50 and 200 µm (micron).
7. The use of the solid polymer electrolyte claimed in claims 1 to 6 in electrochemical devices, as optical and electrochromic displays, and as electrochemical generators and sensors.

Claims for the following Contracting State : ES

1. A process for preparing a solid polymer electrolyte in membrane form, consisting of a solid solution of an ionic compound dissolved in a polyether, characterised by:

a) copolymerizing a vinyl ether of formula:



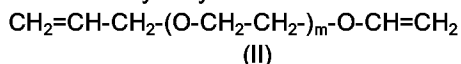
where

R is a methyl or ethyl radical

n is a whole number between 1

and 16,

with an allyl vinyl ether of formula:



where m is a whole number between 1 and 10, the molar ratio of (II) to (I) being between 1/100 and 10/100, to obtain a copolymer having allyl unsaturations;

b) hydrosilylating the allyl double bond of the copolymer obtained in stage a) by reaction with an alkoxysilane chosen from trimethoxy and triethoxy silane, to obtain a hydrosilylated copolymer;

c) cross-linking the hydrosilylated copolymer obtained in stage b) by means of a diprotic cross-linking agent, operating in solution in an organic solvent in the presence of an ionic compound, and evaporating the solvent to obtain a membrane.

2. A process as claimed in claim 1, characterised in that in stage a) the copolymer is prepared by cationic polymerization in an inert solvent at a temperature of about -75/-80°C in the presence of a Friedel-Crafts catalyst in a quantity of between 0.8 and 1.0 moles per 100 moles of the monomers (I) and (II), the copolymer obtained having a weight-average molecular weight of the order of 20,000-100,000 and a glass transition temperature of between -65 and -80°C.
3. A process as claimed in claim 1, characterised in that in stage b) the copolymer prepared in stage

a) is reacted with an alkoxy silane chosen from trimethoxy and triethoxy silane, operating in solution in an anhydrous inert solvent at a temperature of the order of 80-100°C in the presence of a catalyst containing a transition metal.

4. A process as claimed in claim 1, characterised in that in stage c) the hydrosilylated copolymer is cross-linked, using a cross-linking agent chosen from water and an ethyleneglycol acidified with HCl and added in a quantity of about 10-20 micro-litres per gram of copolymer, operating in an organic solvent and preferably acetonitrile, in the presence of an ionic compound chosen from the salts and especially perchlorates, borates, fluoroborates, thiocyanates, trifluoroacetates and trifluoromethanesulphonates of metals (monovalent or polyvalent) and especially lithium, sodium, potassium, calcium, copper, zinc, magnesium, lead, tin and aluminium, in a quantity such as to achieve an atomic ratio of oxygen in the polyether to metal of between about 4/1 and 18/1.

5. A process as claimed in claim 4, characterised in that the ionic compound is a lithium salt and preferably lithium perchlorate, the atomic ratio of oxygen in the polyether to lithium being of the order of 12/1.

6. A process as claimed in claim 4, characterised in that the solution is poured into a mould, the solvent is evaporated and the evaporation residue dried to obtain a membrane having a thickness of between 50 and 200 nm (micron).

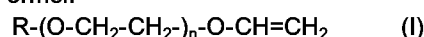
Patentansprüche

Patentansprüche für folgende

Vertragsstaaten : AT, BE, CH, DE, DK, FR, GB, GR, LI, LU, NL, SE

1. Fester Polymerelektrolyt in Membranform, bestehend aus einer festen Lösung einer in einem Polyether gelösten Ionenverbindung, dadurch gekennzeichnet, daß der erwähnte Elektrolyt erhalten wird durch:

a) Copolymerisieren eines Vinylethers der Formel:



worin

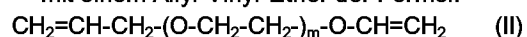
R ein Methyl- oder Ethylradikal

und

n eine ganze Zahl zwischen 1

und 16, ist,

mit einem Allyl-Vinyl-Ether der Formel:



worin m eine ganze Zahl zwischen 1

- und 10 ist,
wobei das molare Verhältnis von (II) zu (I) zwischen 1/100 und 10/100 liegt, so daß ein Copolymer mit Allyl-Ungesättigkeiten erhalten wird;
- b) Hydrosilylierung der Allyl-Doppelbindung des in Stufe a) erhaltenen Copolymers durch Reaktion mit einem Alkoxysilan, das ausgewählt ist aus Trimethoxy- und Triethoxy-Silan, zur Erzielung eines hydrosilylierten Copolymers;
- c) Vernetzung des in Stufe b) erhaltenen hydrosilylierten Copolymers mittels eines diprotischen Vernetzungsmittels, wobei in Lösung in einem organischen Lösungsmittel in der Gegenwart einer Ionenverbindung gearbeitet wird, und Verdampfung des Lösungsmittels, um die Membran zu erhalten.
2. Fester Polymerelektrolyt nach Anspruch 1, dadurch gekennzeichnet, daß in Stufe a) das Copolymer durch kationische Polymerisation in einem inerten Lösungsmittel bei einer Temperatur von etwa -75/-80°C in Gegenwart eines Friedel-Crafts-Katalysators in einer Menge zwischen 0,8 und 1,0 mol pro 100 mol der Monomere (I) und (II) erzeugt wird, wobei das erhaltene Copolymer ein durchschnittliches Molekulargewicht in der Größenordnung von 20.000 bis 100.000 und eine Einfriertemperatur zwischen -65 und -80°C aufweist.
3. Fester Polymerelektrolyt nach Anspruch 1, dadurch gekennzeichnet, daß in Stufe b) das in Stufe a) hergestellte Copolymer mit einem Alkoxysilan zur Reaktion gebracht wird, das ausgewählt ist aus Trimethoxy- und Triethoxy-Silan, wobei in Lösung in einem wasserfreien inerten Lösungsmittel bei einer Temperatur in der Größenordnung von 80 bis 100°C in Gegenwart eines Katalysators gearbeitet wird, der ein Übergangsmetall enthält.
4. Fester Polymerelektrolyt nach Anspruch 1, dadurch gekennzeichnet, daß in Stufe c) das hydrosilylierte Copolymer vernetzt ist, wobei ein Vernetzungsmittel verwendet wird, das aus Wasser und einem mit HCl angesäuertem Ethylenglycol ausgewählt ist und in einer Menge von etwa 10 bis 20 Mikroliter pro Gramm des Copolymers zugesetzt wird, wobei in einem organischen Lösungsmittel, vorzugsweise Acetonitril, in Gegenwart einer Ionenverbindung gearbeitet wird, die ausgewählt ist aus Salzen, insbesondere Perchloraten, Boraten, Fluorboraten, Thiocyanaten, Trifluoracetaten und Trifluormethansulphonaten von Metallen (einwertig oder mehrwertig), insbesondere Lithium, Natrium, Kalium, Calcium, Kupfer, Zink, Magnesium, Blei, Zinn und Aluminium, in einer derartigen Menge, daß ein Atomverhältnis von Sauerstoff im Polyether zu Metall von zwischen etwa 4/1 und 18/1 erhalten wird.
5. Fester Polymerelektrolyt nach Anspruch 4, dadurch gekennzeichnet, daß die Ionenverbindung ein Lithiumsalz, vorzugsweise Lithiumperchlorat, ist, wobei das Atomverhältnis von Sauerstoff im Polyether zu Lithium in der Größenordnung von 12/1 liegt.
6. Fester Polymerelektrolyt nach Anspruch 4, dadurch gekennzeichnet, daß die Lösung in eine Form gegossen wird, das Lösungsmittel verdampft wird und der Verdampfungsrückstand getrocknet wird, um eine Membran mit einer Dicke zwischen 50 und 200 µm (Micron) zu erhalten.
7. Die Verwendung eines festen Polymerelektrolyten nach den Ansprüchen 1 bis 6 in elektrochemischen Einrichtungen, wie optischen und elektrochromen Displays, elektrochemischen Generatoren und Sensoren.

Patentansprüche für folgende Vertragsstaat : ES

1. Verfahren zur Herstellung eines festen Polymerelektrolyten in Membranform, bestehend aus einer festen Lösung einer in einem Polyether gelösten Ionenverbindung, gekennzeichnet durch
- a) Copolymerisieren eines Vinylethers der Formel:
- $$R-(O-CH_2-CH_2)_n-O-CH=CH_2 \quad (I)$$
- worin
- R ein Methyl- oder Ethylradikal
- und
- n eine ganze Zahl zwischen 1 und 16, ist,
- mit einem Allyl-Vinyl-Ether der Formel:
- $$CH_2=CH-CH_2-(O-CH_2-CH_2)_m-O-CH=CH_2 \quad (II)$$
- worin m eine ganze Zahl zwischen 1 und 10 ist,
- wobei das molare Verhältnis von (II) zu (I) zwischen 1/100 und 10/100 liegt, so daß ein Copolymer mit Allyl-Ungesättigkeiten erhalten wird;
- b) Hydrosilylierung der Allyl-Doppelbindung des in Stufe a) erhaltenen Copolymers durch Reaktion mit einem Alkoxysilan, das ausgewählt ist aus Trimethoxy- und Triethoxy-Silan, zur Erzielung eines hydrosilylierten Copolymers;
- c) Vernetzung des in Stufe b) erhaltenen hydrosilylierten Copolymers mittels eines diprotischen Vernetzungsmittels, wobei in Lösung in einem organischen Lösungsmittel in

der Gegenwart einer Ionenverbindung gearbeitet wird, und Verdampfung des Lösungsmittels, um die Membran zu erhalten.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß in Stufe a) das Copolymer durch kationische Polymerisation in einem inerten Lösungsmittel bei einer Temperatur von etwa -75/-80°C in Gegenwart eines Friedel-Crafts-Katalysators in einer Menge zwischen 0,8 und 1,0 mol pro 100 mol der Monomere (I) und (II) erzeugt wird, wobei das erhaltene Copolymer ein durchschnittliches Molekulargewicht in der Größenordnung von 20.000 bis 100.000 und eine Einfriertemperatur zwischen -65 und -80°C aufweist. 5
3. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß in Stufe b) das in Stufe a) hergestellte Copolymer mit einem Alkoxy-Silan zur Reaktion gebracht wird, das ausgewählt ist aus Trimethoxy- und Triethoxy-Silan, wobei in Lösung in einem wasserfreien inerten Lösungsmittel bei einer Temperatur in der Größenordnung von 80 bis 100°C in Gegenwart eines Katalysators gearbeitet wird, der ein Übergangsmetall enthält. 10
4. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß in Stufe c) das hydrosilylierte Copolymer vernetzt ist, wobei ein Vernetzungsmittel verwendet wird, das aus Wasser und einem mit HCl angesäuertem Ethylenglycol ausgewählt ist und in einer Menge von etwa 10 bis 20 Mikroliter pro Gramm des Copolymers zugesetzt wird, wobei in einem organischen Lösungsmittel, vorzugsweise Acetonitril, in Gegenwart einer Ionenverbindung gearbeitet wird, die ausgewählt ist aus Salzen, insbesondere Perchloraten, Boraten, Fluorboraten, Thiocyanaten, Trifluoracetaten und Trifluormethansulphonaten von Metallen (einwertig oder mehrwertig), insbesondere Lithium, Natrium, Kalium, Calcium, Kupfer, Zink, Magnesium, Blei, Zinn und Aluminium, in einer derartigen Menge, daß ein Atomverhältnis von Sauerstoff im Polyether zu Metall von zwischen etwa 4/1 und 18/1 erhalten wird. 15
5. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß die Ionenverbindung ein Lithiumsalz, vorzugsweise Lithiumperchlorat, ist, wobei das Atomverhältnis von Sauerstoff im Polyether zu Lithium in der Größenordnung von 12/1 liegt. 20
6. Verfahren nach Anspruch 4, dadurch gekennzeichnet, daß die Lösung in eine Form gegossen wird, das Lösungsmittel verdampft wird und der Verdampfungsrückstand getrocknet wird, um eine 25

ne Membran mit einer Dicke zwischen 50 und 200 µm (Micron) zu erhalten.

Revendications

Revendications pour les Etats contractants suivants : AT, BE, CH, DE, DK, FR, GB, GR, LI, LU, NL, SE

1. Electrolyte polymère solide sous forme de membrane, constitué d'une solution solide d'un composé ionique dissous dans un polyéther, caractérisé en ce qu'on obtient cet électrolyte en effectuant : 30
 - a) la copolymérisation d'un éther de vinyle de formule

$$\text{R-(O-CH}_2\text{-CH}_2\text{)}_n\text{-O-CH=CH}_2 \quad (\text{I})$$
 dans laquelle R représente un groupe méthyle ou éthyle et n représente un nombre entier valant de 1 à 16,
 et d'un éther d'allyle et de vinyle de formule

$$\text{CH}_2=\text{CH-CH}_2\text{-(O-CH}_2\text{-CH}_2\text{)}_m\text{-O-CH=CH}_2 \quad (\text{II})$$
 dans laquelle m représente un nombre entier valant de 1 à 10,
 le rapport molaire de (II) à (I) valant de 1/100 à 10/100, afin d'obtenir un copolymère comportant des groupes insaturés de type allyle; 35
 - b) l'hydrosilylation des doubles liaisons allyliques du copolymère obtenu lors de l'étape (a), par réaction avec un alcoxysilane choisi parmi le triméthoxysilane et le triéthoxysilane, afin d'obtenir un copolymère hydrosilylé ; 40
 - c) la réticulation du copolymère hydrosilylé obtenu lors de l'étape (b), à l'aide d'un agent diprotique de réticulation, en opérant en solution dans un solvant organique et en présence d'un composé ionique, et l'évaporation du solvant afin d'obtenir une membrane. 45
2. Electrolyte polymère solide conforme à la revendication 1, caractérisé en ce que, dans l'étape (a), on prépare le copolymère par polymérisation cationique, dans un solvant inerte, à une température d'environ -75°C à -80°C, en présence d'un catalyseur de Friedel-Crafts utilisé en une proportion de 0,8 à 1,0 mole pour 100 moles des monomères (I) et (II), le copolymère obtenu présentant une masse moléculaire moyenne en poids de l'ordre de 20 000 à 100 000 et une température de transition vitreuse située entre -65°C et -80°C. 50
3. Electrolyte polymère solide conforme à la revendication 1, caractérisé en ce que, dans l'étape (b), on fait réagir le copolymère préparé lors de l'étape (a) avec un alcoxysilane choisi parmi le triméthoxysilane et le triéthoxysilane, en opérant en 55

solution dans un solvant anhydre inerte, à une température de l'ordre de 80°C à 100°C et en présence d'un catalyseur contenant un métal de transition.

4. Electrolyte polymère solide conforme à la revendication 1, caractérisé en ce que, dans l'étape (c), on effectue la réticulation du copolymère hydrosilylé en utilisant un agent de réticulation choisi parmi l'eau et l'éthylèneglycol, acidifié par de l'acide chlorhydrique et ajouté en une proportion d'environ 10 à 20 microlitres par gramme de copolymère, en opérant dans un solvant organique qui est de préférence de l'acétonitrile, en présence d'un composé ionique choisi parmi les sels, spécialement les perchlorates, borates, borofluorures, thiocyanates, trifluoroacétates et trifluorométhanesulfonates, de métaux monovalents ou polyvalents, spécialement lithium, sodium, potassium, calcium, cuivre, zinc, magnésium, plomb, étain et aluminium, utilisé en une quantité appropriée pour que le rapport atomique de l'oxygène présent dans le polyéther au métal vaille d'environ 4/1 à environ 18/1.

5. Electrolyte polymère solide conforme à la revendication 4, caractérisé en ce que le composé ionique est un sel de lithium, de préférence du perchlorate de lithium, et en ce que le rapport atomique de l'oxygène présent dans le polyéther au lithium est de l'ordre de 12/1.

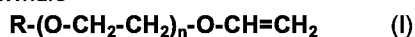
6. Electrolyte polymère solide conforme à la revendication 4, caractérisé en ce qu'on verse la solution dans un moule, on fait s'évaporer le solvant et on fait sécher le résidu d'évaporation, afin d'obtenir une membrane dont l'épaisseur vaut entre 50 et 200 µm (micromètres).

7. Emploi d'un électrolyte polymère solide conforme à l'une des revendications 1 à 6 dans des dispositifs électrochimiques, en tant qu'afficheurs optiques et électrochromiques, et en tant que générateurs et capteurs électrochimiques.

Revendications pour l'Etat contractant suivant : ES

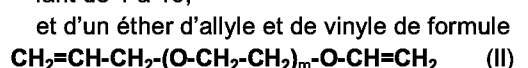
1. Procédé de préparation d'un électrolyte polymère solide sous forme de membrane, constitué d'une solution solide d'un composé ionique dissous dans un polyéther, caractérisé en ce qu'on effectue :

a) la copolymérisation d'un éther de vinyle de formule



dans laquelle R représente un groupe méthyle ou éthyle et n représente un nombre entier va-

lant de 1 à 16,



dans laquelle m représente un nombre entier valant de 1 à 10,

le rapport molaire de (II) à (I) valant de 1/100 à 10/100, afin d'obtenir un copolymère comportant des groupes insaturés de type allyle ;

b) l'hydrosilylation des doubles liaisons allyliques du copolymère obtenu lors de l'étape (a), par réaction avec un alcoxysilane choisi parmi le triméthoxysilane et le triéthoxysilane, afin d'obtenir un copolymère hydrosilylé ;

c) la réticulation du copolymère hydrosilylé obtenu lors de l'étape (b), à l'aide d'un agent diprotique de réticulation, en opérant en solution dans un solvant organique et en présence d'un composé ionique, et l'évaporation du solvant afin d'obtenir une membrane.

2. Procédé conforme à la revendication 1, caractérisé en ce que, dans l'étape (a), on prépare le copolymère par polymérisation cationique, dans un solvant inerte, à une température d'environ -75°C à -80°C, en présence d'un catalyseur de Friedel-Crafts utilisé en une proportion de 0,8 à 1,0 mole pour 100 moles des monomères (I) et (II), le copolymère obtenu présentant une masse moléculaire moyenne en poids de l'ordre de 20 000 à 100 000 et une température de transition vitreuse située entre -65°C et -80°C.

3. Procédé conforme à la revendication 1, caractérisé en ce que, dans l'étape (b), on fait réagir le copolymère préparé lors de l'étape (a) avec un alcoxysilane choisi parmi le triméthoxysilane et le triéthoxysilane, en opérant en solution dans un solvant anhydre inerte, à une température de l'ordre de 80°C à 100°C et en présence d'un catalyseur contenant un métal de transition.

4. Procédé conforme à la revendication 1, caractérisé en ce que, dans l'étape (c), on effectue la réticulation du copolymère hydrosilylé en utilisant un agent de réticulation choisi parmi l'eau et l'éthylèneglycol, acidifié par de l'acide chlorhydrique et ajouté en une proportion d'environ 10 à 20 microlitres par gramme de copolymère, en opérant dans un solvant organique qui est de préférence de l'acétonitrile, en présence d'un composé ionique choisi parmi les sels, spécialement les perchlorates, borates, borofluorures, thiocyanates, trifluoroacétates et trifluorométhanesulfonates, de métaux monovalents ou polyvalents, spécialement lithium, sodium, potassium, calcium, cuivre, zinc, magnésium, plomb, étain et aluminium, utilisé en une quantité appropriée

pour que le rapport atomique de l'oxygène présent dans le polyéther au métal vaille d'environ 4/1 à environ 18/1.

5. Procédé conforme à la revendication 4, caractérisé en ce que le composé ionique est un sel de lithium, de préférence du perchlorate de lithium, et en ce que le rapport atomique de l'oxygène présent dans le polyéther au lithium est de l'ordre de 12/1.

6. Procédé conforme à la revendication 4, caractérisé en ce qu'on verse la solution dans un moule, on fait s'évaporer le solvant et on fait sécher le résidu d'évaporation, afin d'obtenir une membrane dont l'épaisseur vaut entre 50 et 200 μm (micromètres).

20

25

30

35

40

45

50

55

10

